2MASS observations of spectroscopically identified extragalactic C stars

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ABSTRACT

We matched spectroscopically identified C stars (from low resolution objective prism surveys) in the Magellanic Clouds with 2MASS sources. We confirm that C stars show a large spread in absolute magnitudes, even in the K_s band. We show that the I and K_s magnitude distributions of a population of C stars (in the LMC) have a similar narrow dispersion if the C stars are selected in a well defined color range. Using magnitude and color criteria, we employ the 2MASS data to identify 26 C stars in the the Fornax dwarf spheroidal galaxy.

The mean K_s magnitude and the mean bolometric magnitude of C stars are found to be slightly brighter in the LMC and SMC when compared to those of the Fornax dwarf spheroidal galaxy. The difference could be explained by ages or/and abundance differences.

Subject headings: galaxies: Magellanic Clouds — galaxies: individual (Fornax) — stars: carbon — techniques: photometric

1. Introduction

Thanks to the 2MASS survey (Skrutskie et al. 1997) the astronomical community has now J, H, and K_s magnitudes for almost all the brighter stars of the Magellanic Clouds and a number of nearby galaxies, since their (S/N = 10) magnitude limits are respectively 16.3, 15.3 and 14.7. These observations are particularly suitable to investigate the red giant branch (RGB) and asymptotic giant branch (AGB) populations of nearby galaxies. Because the Magellanic Clouds are nearby, stars of fainter absolute magnitudes have been acquired by 2MASS. Indeed, Nikolaev & Weinberg (2000) have used the 2MASS data to investigate the spatial distribution of several types of stars of the Large Magellanic Cloud (LMC). The

various types of stars were defined by their location on the K_s vs $(J - K_s)$ color-magnitude diagram.

What is of immediate interest to us is their J region which contains carbon-rich AGB stars and is defined by a sample of C-rich long period variables from Hughes & Wood (1990). Nikolaev & Weinberg (2000) state that stars in this region of the CMD are potentially good standard candles because their K_s magnitude spread is quite small, providing that stars are selected in a narrow color range. This important aspect has been followed up by Weinberg & Nikolaev (2001) to probe the three-dimensional structure of the LMC. They, however, restrict even more the color interval of the stars in the J region by selecting only stars in the range $1.6 < J - K_s < 1.7$.

This approach is quite impressive, but it can be applied only when thousands of stars are available since the narrow color range reduces appreciably the size of the sample. The question we ask then, is how useful will be the K_s magnitudes of C stars if one were to select stars in the J region ($1.4 < J–K_s < 2.0$) rather than the narrower color range. The goal of this approach is to investigate C star populations in other nearby galaxies where dozens of C stars are seen rather than thousands.

2. The C star samples

We search the 2MASS database to obtain magnitudes of two sets of spectroscopically identified C stars. By *spectroscopically identified* we mean low resolution slitless objective prism spectroscopy. Such surveys in crowded fields produce spurious identification for faint objects. They are:

1– Set **KDMK**: Kontizas et al. (2001) recently published a catalogue of 7760 C stars in the LMC. The stars were identified from an objective prism survey of the LMC with the

UK Schmidt Telescope. The authors provide RI photographic magnitudes obtained from the UK Schmidt plates. Their list includes hundreds of stars, observed in RI, by Costa & Frogel (1996). The comparison of the magnitudes and colors reveals that it is quite difficult to achieve any accuracy with UK Schmidt photographic photometry. We will not use these magnitudes and colors.

2– Set **MH**: 1185 C stars in ~ 220 deg^2 covering the SMC and the inter-cloud region are identified by Morgan & Hatzidimitriou (1995) from UK Schmidt Telescope objective-prism plates. Neither magnitudes nor colors are available for these stars.

Two other sets of Magellanic Cloud C stars were considered but not retained, they are: the list of C stars in the periphery of the LMC and SMC spectroscopically identified by Kunkel, Irwin & Demers (1997) and Kunkel, Demers & Irwin (2000). Nearly all of these stars are included in the LMC KDMK and the MH SMC sets. Costa & Frogel (1996) have published I and (R–I) for hundreds of C stars in the LMC. Their stars were selected from lists of objective prism spectral identifications by Blanco et al. (1980) and Blanco & McCarthy (1983). Unfortunately, these stars have rather poorly established equatorial coordinates. Cross identifications with 2MASS sources lead to matches as far off as 30 arcsec from the best 2MASS candidates. For this reason we prefer not to use directly the original coordinates. Most of these stars are expected to be in the KDMK set but they were not all cross identified by Kontizas et al. (2001).

3. Color-magnitude diagrams

7078 stars of the KDMK set were matched, within 2 arcsec of 2MASS sources. These stars are displayed on the color magnitude diagram in Figure 1. It is obvious that spectroscopically identified C stars possess a wide range of K$_s$ magnitudes and (J–K$_s$)

colors. This figure shows that C stars are found not only on the AGB tip but also at lower magnitudes on the AGB which nearly coincides, in magnitudes and colors, with the giant branch. The parallelogram outlines the J region, defined by Nikolaev & Weinberg (2000) where C stars have a small range of K_s magnitudes. We adopt its color boundaries as: 1.4 < J–K < 2.0, the upper and lower magnitude boundaries depend on the distance of the C stars.

EDITOR: PLACE FIGURE 1 HERE.

The variable color excess within the LMC and the effect of the depth of the LMC on the apparent magnitudes increase the K_s dispersion of C stars. The East - West inclination of the disc of the LMC introduces a ± 0.2 apparent magnitude dispersion (Nikolaev & Weinberg 2000). The bulk of the C stars are near the center/bar, thus only the relatively few in the periphery would contribute to the widening of the distribution. The extinction, A_K, is at most a few hundredth of a magnitude (Nikolaev & Weinberg 2000). Cioni et al. (2000) adopt $A_K = 0.04$ for both Magellanic Clouds. The K_s magnitude distribution of the 7078 LMC C stars is shown in Figure 2. The shade histogram corresponds to stars with J–K colors in the 1.4 to 2.0 range. Obviously, the K_s magnitudes are better defined by selecting C stars in a narrow color interval; the FWHM of the shaded distribution is 0.33 mag. No correction has been made for the color excess. Since E(J–K) = 0.65E(B-V), the reddening corrections are expected to be ≈ 0.07 mag.

EDITOR: PLACE FIGURE 2 HERE.

EDITOR: PLACE FIGURE 3 HERE.

The MH set yields 1093 matches. The CMD of this set is presented in Figure 3. As in the LMC case, we observe that spectroscopically identified C stars show a large range of K_s magnitudes. Figure 4 compares the magnitude distributions of the LMC and SMC C stars located in the J region. The average total reddening toward the two Magellanic Clouds is nearly similar (Westerlund 1997). The mean magnitude of the distributions being respectively 10.68 and 11.26 for a difference of 0.58 mag.

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4.   Color-color diagrams

The photometric properties of C stars in the color-color diagram have been investigated by Cohen et al. (1981). They found slight differences, explained by the different metallicities between the LMC, SMC and Galactic C star populations. Figure 5 displays the color-color diagram of the LMC C stars. The two solid lines outline the J–K limits of the J region. Ninety nine percent of the stars in the J region are within the box limited by the two dashed lines.

EDITOR: PLACE FIGURE 5 HERE.

The SMC C stars are displayed on the color-color diagram in Figure 6, the same box than Fig. 5 is shown. One notes that SMC C stars are indeed slightly displaced in colors relative to the LMC ones.

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5.   DISCUSSION

5.1.   Comparison of $\langle I \rangle$ and $\langle K_s \rangle$

Albert, Demers & Kunkel (2000) and Letarte et al. (2002) have shown that, when a large C star population is observed in a galaxy, the C star M_I magnitude distribution has a narrow FWHM. We are now in position to compare the dispersion of I and K_s magnitudes of C stars. To do so we have, however, to photometrically select a sub-sample of C stars with well defined colors and not simply accept all spectroscopically defined C stars. We already know that, for all C stars, there is a substantial magnitude spread. For the purpose of our comparison we need C stars with I and K_s magnitudes. Costa & Frogel (1996) have obtained RI magnitudes of some 800 spectroscopically identified C stars in the LMC. Following our adopted color criterion, we select only C stars with $(R–I)_o > 0.90$, see for example, Albert et al. (2000); Battinelli & Demers (2000) or the corresponding V–I criterion of Brewer, Richer & Crabtree (1996). Some 300 C stars satisfying this criterion have been observed by Costa & Frogel (1996) and are cross identified in the KDMK data set. We thus have also the K_s magnitude of these stars. It is rather interesting to note that the R–I color criterion is rather similar to the J region criterion in the K_s vs J–K_s plane. Indeed, on Figure 7 we plot the 300 LMC C stars used for our comparison. Eighty seven percent of the stars are in the J region.

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The comparison of the I and K_s magnitude distributions, shown in Figure 8, reveals that C stars, selected as described above, have a *narrower* I_o magnitude distribution than K_s. One must however take note that Costa & Frogel (1996) have corrected their magnitudes for reddening while the K_s are not corrected. They adopt a mean A_I for a given area, based on the extinction of clusters. Since the reddening was not determined for each star, one must

consider it approximate. We redetermined the I_o magnitude distribution by adding to the magnitudes a random reddening variation ranging up to E(R–I) = ± 0.05, corresponding to a maximum A_I = ± 0.12, values quite reasonable for the LMC. The only effect of this extinction variation is to increase slightly the width of the magnitude distrition, keeping it narrower than the K_s magnitude distribution. The A_K variation across the face of the LMC is expected to be small and probably does not explain the larger width of the distribution. ¿From the two mean magnitudes, $\langle I_o \rangle$ = 13.8 and $\langle K_s \rangle$ = 10.6 we see that C stars are 3.2 magnitudes brighter in K_s than in I. It does not follow, however, that K_s observations of C stars are more time efficient than I observations. The sky is so much brighter in the K band than the I band than to obtain similar S/N, a much longer exposure time is required in K_s than in the I band.

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5.2. The 2MASS survey toward Fornax

The Fornax dwarf spheroidal galaxy, the most massive of the dwarf spheroidal associated with the Milky Way has been known for over twenty years to contain an intermediate age population and carbon stars (Demers & Kunkel 1979; Aaronson & Mould 1980). During the last decades, spectroscopic surveys have permitted the identification of dozens of C stars in Fornax. Azzopardi (1999) mentions that there are 104 known C stars but barely half of these have published coordinates, magnitudes or colors.

EDITOR: PLACE FIGURE 9 HERE.

We have found 4365 2MASS sources within one degree from the center of Fornax and with a signal in the three bands. The color-magnitude diagram of these sources, presented in

Figure 9, reveals that only a few stars are have the right color to be C stars. Taking, $(m-M)_o = 20.76$ for the true modulus of Fornax (Demers, Kunkel & Grondin 1990; Saviane, Held & Bertelli 2000), one would expect C stars to have $K_s \approx 13$. Indeed, inspection of the J–K_s color errors as a function of the apparent magnitudes shows that for $K_s > 14.0$ photometric errors become larger than ± 0.1 mag. This implies that stars seen on the CMD near the magnitude limit have poorly determined magnitudes and colors. We therefore select only stars, in the J region with photometric errors less than 0.1 mag as possibly Fornax C star candidates. The stars in the J region, which satisfy the above magnitude criterion fall in the expected rectangle in the color-color diagram, shown in Figure 10.

EDITOR: PLACE FIGURE 10 HERE.

We have thus identify, using JHK$_s$ photometry, 26 C stars in Fornax. They represent a sub-sample of the C star population of Fornax because we select stars in a well defined color range. These C stars are given in Table 1. Listed are their Equatorial J2000 coordinates, and their 2MASS magnitudes and colors. Cross identifications with previously known C stars or known red stars are given in Table 2. We include here V, B–V (photographic magnitudes) from Demers, Irwin & Kunkel (1994) when available. Most of the 26 C stars are already spectroscopically identified C stars. Seven of them are newly confirmed C stars, including two not found in our database of red stars in Fornax. The newly identified C stars are in the periphery of Fornax, outside of the regions previously surveyed by low dispersion spectroscopy by Frogel et al. (1982) and Westerlund et al. (1987).

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The mean K_s magnitude of the 26 identified C stars of Fornax is $\langle K_s \rangle = 13.08$, corresponding to $\langle M_{K_s} \rangle = -7.68$ for the adopted distance given above. The reddening toward Fornax is quite small, E(B–V) $\approx$ 0.03 thus negligible in the K band.

5.3. The constancy of $\langle M_{K_s} \rangle$ from galaxy to galaxy.

Having obtained the mean K_s for the C star population of three galaxies we investigate the effect of the metallicity on the mean absolute and bolometric magnitudes. We adopt the distances of the LMC and SMC recently determined, from the tip of the giant branches, by Cioni et al. (2000): $(m–M)_o$ = 18.55 ±0.04, for the LMC and $(m–M)_o$ = 18.99 ±0.03 for the SMC along with A_{K_s} = 0.04 for both galaxies. Our mean magnitudes yield: $\langle M_{K_s} \rangle$ = –7.91 for the LMC and $\langle M_{K_s} \rangle$ –7.77 for the SMC. The difference between these two magnitudes is larger than the uncertainties on the distances and the reddening.

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Table 3 summarizes our findings. The abundance of C stars in the LMC and SMC are expected to be somewhat less than the canonical metallicities which correspond to younger populations rather than the intermediate age ones. Intermediate age clusters were found to have [Fe/H] = –0.6, in the LMC (Rich, Shara, Zurek 2001) and $-1.6 < [Fe/H] < -1.1$ for the SMC (Piatti et al. 2001). Table 3 shows that C stars are slightly brighter, in the K_s band, in metal rich systems. The magnitude trend, seen in Table 3, is contrary to what Demers & Battinelli (2002) have observed for the $\langle M_I \rangle$ of C stars in several Local Group galaxies. In the I band, C stars are brighter in the metal poorest systems.

This effect is, however, not unexpected. Indeed, the AGB tip of Bertelli's et al. (1994) isochrones is 0.3 mag. brighter in K for a metallicity [Fe/H] = –0.5 than it is for [Fe/H] = –1.5. The AGB tip is however 0.6 mag. fainter in I for the high metallicity than it is for the

low metallicity. The absolute magnitude variations are thus confirmed by the isochrones. These isochrones, however, reach only J–K = 1.2, a color bluer than the adopted color range of C stars.

We also transform the K_s magnitudes into bolometric magnitudes using Frogel, Persson & Cohen (1980) relation. Nikolaev & Weinberg (2000) have shown that the K_s magnitude is essentially equivalent to the K magnitude. We adopt, for the LMC and SMC a mean extinction of $A_K = 0.04$ and reddening of E(J–K) = 0.13. There is a slightly larger dispersion among the mean bolometric magnitudes compared to the mean M_{K_s} magnitudes of the three galaxies listed in Table 3.

Recent isochrones, specifically calculated for carbon stars, by Mouhcine (2002) reveal that the bolometric magnitudes and M_{K_s} of C stars are function of their age and of their abundance. C stars in the 0.3 to 1 Gyr range are ~ 1 mag. brighter than their older cousins. The brighter mean M_{K_s} of C stars in the LMC and SMC could then be due to the presence of numerous younger C stars, such stars are absent in Fornax.

6. CONCLUSION

The R–I, CN–TiO approach to identify C stars in galaxies is equivalent to the JHK_s photometric technique. The magnitude dispersions of C stars in K_s and I are about the same. Even if C stars are ~ 3 magnitudes brighter in K_s than in I, the sky brightness in K_s is such that the exposure times in the near infrared are in fact longer than in R or I. The narrow CN and TiO filters require however much longer exposures than I or R to reach similar S/N. For this reason the JHK_s photometry is approximately equivalent in telescope time to the four band photometry. The facts that CN and TiO filters are unavailable in most observatories and that the new larger telescopes favor near infrared cameras make the

JHK_s approach more promising to survey galaxies in the neighborhood of the Local Group.

REFERENCES

Aaronson, M., & Mould, J. 1980, ApJ, 240, 804

Albert, L., Demers, S., & Kunkel, W. E. 2000, AJ, 119, 2780

Azzopardi, M. 1999, Ap&SS, 265, 291

Battinelli, P., & Demers, S. 2000, AJ, 120, 1801

Bertelli, G., Bressan, A. Chiosi, C., Fagotto, F., & Nasi, E. 1994, A&AS, 106, 275

Blanco, V. M., McCarthy, M. F., & Blanco, B. M. 1980, ApJ, 242, 938

Blanco, V. M., & McCarthy, M. F. 1983, AJ, 88, 1442

Brewer, J. P., Richer, H. B., & Crabtree, D. R. 1996, AJ, 112, 491

Cioni, M. R. L., van der Marel, R. P., Loup, C, & Habing, H. J. 2000, A&A, 359, 601

Cohen, J. G., Persson, S. E., Elias, J. H., & Frogel, J. A. 1981, ApJ, 249, 481

Costa, E., & Frogel, J. A. 1996, AJ, 112, 2607

Demers, S., & Battinelli, P. 2002, AJ, 123, 238

Demers, S., & Kunkel, W. E. 1979, PASP, 91, 761

Demers, S., & Irwin, M. J. 1987, MNRAS, 226, 943

Demers, S., Kunkel, W. E., & Grondin, L. 1990, PASP, 102, 632

Demers, S., Irwin, M. J., & Kunkel, W. E, 1994, AJ, 108, 1648

Frogel, J. A., Persson, S. E., & Cohen, J. G. 1980, ApJ, 239, 495

Frogel, J. A., Blanco, V. M., McCarthy, M. F., & Cohen, J. G. 1982, ApJ, 252, 133

Hughes, S. M. G., & Wood, P. R. 1990 AJ, 99, 784

Kontizas, E., Dapergolas, A., Morgan, D. H., & Kontizas, M. 2001, A&A, 369, 932

Kunkel, W. E., Irwin, M. J., & Demers, S. 1997, A&AS, 122, 463

Kunkel, W. E., Demers, S., & Irwin, M. J. 2000, AJ, 119, 2789

Letarte, B., Demers, S., Battinelli, P., & Kunkel, W. E. 2002, AJ, in press

Morgan, D. H., & Hatzidimitriou, D. 1995, A&AS, 113, 539

Mouhcine, M. 2002, A&A, submitted

Nikolaev, S., & Weinberg, M. D. 2000, ApJ, 542, 804

Piatti, A. E., Santos, J. F. C., Claria, J. J. Bica, E., Sarajedini, A., & Geisler, D. 2001, MNRAS, 325, 792

Rich, R. M., Shara, M. M., & Zurek, D. 2001, AJ, 122, 842

Saviane, I., Held, E. V., & Bertelli, G. 2000, A&A, 355, 56

Skrutskie, M. F., et al. 1997, in The Impact of Large Scale Near-IR Sky Surveys, ed. F. Garzon (Dordrecht; Kluwer), 187

Weinberg, M. D. & Nikolaev, S. 2001, ApJ, 548, 712

Westerlund, B. E. 1997 in The Magellanic Clouds, Cambridge U. Press, Cambridge UK

Westerlund, B. E., Edvardsson, B., & Lundgren, K. 1987, A&A, 178, 41

Fig. 1.— Color-magnitude diagram of LMC spectroscopically identified C stars. The parallelogram traces the J region where C stars with homogeneous properties are found.

Fig. 2.— Magnitude distribution of LMC C stars. The shaded histogram represents the C stars in the J region.

Fig. 3.— Color-magnitude diagram of SMC spectroscopically identified C stars. The J region is lowered by half a magnitude relative to Figure 1.

Fig. 4.— Comparison of the K_s LMC and SMC magnitude distributions of C stars in the J region.

Fig. 5.— The color-color diagram of the LMC C stars. The solid lines trace the 1.4 < J–K < 2.0 limits. 99% of the C stars within these limits are inside of the dashed lines.

Fig. 6.— The color-color diagram of the SMC C stars. The box is at the same position than on the previous figure.

Fig. 7.— Spectroscopically identified C stars with $(R - I)_o > 0.90$. Nearly all of them fall into the J region.

Fig. 8.— Comparison of the magnitude distribution of a sample of LMC C stars selected from a R–I color criterion.

Fig. 9.— Color-magnitude diagram of the 2MASS sources in a circle of 1 degree radius centered on the Fornax dwarf spheroidal galaxy. The color limits of the J region are outlined.

Fig. 10.— Stars in the J region outlined in Figure 9 with color errors less than 0.1 mag. fall in the expected region of C stars. These stars have K_s magnitudes between 12 and 14.

Table 1.   C stars identified by 2MASS in Fornax

id	RA	Dec	K_s	σ_{K_s}	J–H	σ_{J-H}	H–K_s	σ_{H-K_s}	J–K_s	σ_{J-K_s}
1	2 37 40.6	–34 20 08	13.941	0.058	1.051	0.083	0.558	0.083	1.609	0.083
2	2 38 57.0	–34 46 34	13.061	0.039	1.151	0.054	0.593	0.054	1.744	0.054
3	2 38 58.3	–34 32 11	13.203	0.042	1.086	0.059	0.574	0.055	1.660	0.059
4	2 39 31.8	–34 36 39	13.131	0.037	0.961	0.051	0.697	0.054	1.658	0.051
5	2 39 34.4	–34 37 14	13.023	0.040	0.956	0.051	0.492	0.058	1.448	0.051
6	2 39 34.7	–34 38 57	13.622	0.063	1.028	0.076	0.478	0.080	1.506	0.076
7	2 39 37.4	–34 36 26	12.936	0.035	1.100	0.050	0.709	0.057	1.809	0.050
8	2 39 40.6	–34 20 14	12.419	0.029	0.992	0.039	0.478	0.040	1.470	0.039
9	2 39 48.5	–34 35 07	12.826	0.034	1.118	0.056	0.625	0.049	1.743	0.056
10	2 39 51.9	–34 33 20	12.683	0.037	1.173	0.053	0.570	0.057	1.743	0.053
11	2 39 55.2	–34 25 26	12.921	0.035	0.916	0.047	0.537	0.047	1.453	0.047
12	2 39 58.4	–34 36 21	13.096	0.036	0.959	0.049	0.485	0.048	1.444	0.049
13	2 40 00.9	–34 22 43	12.992	0.037	1.094	0.050	0.413	0.048	1.507	0.050
14	2 40 02.5	–34 27 42	13.304	0.046	1.185	0.063	0.603	0.062	1.788	0.063
15	2 40 02.7	–34 31 48	13.176	0.041	1.023	0.054	0.551	0.054	1.574	0.054
16	2 40 05.4	–34 32 18	12.867	0.036	1.019	0.048	0.571	0.048	1.590	0.048
17	2 40 06.7	–34 23 22	12.582	0.031	1.102	0.044	0.774	0.044	1.876	0.044
18	2 40 09.1	–34 34 39	13.169	0.043	1.065	0.053	0.441	0.054	1.506	0.053
19	2 40 10.2	–34 33 21	12.517	0.032	0.935	0.042	0.582	0.041	1.517	0.042
20	2 40 15.6	–34 34 02	13.207	0.041	1.074	0.058	0.610	0.055	1.684	0.058

Table 1—Continued

id	RA	Dec	K_s	σ_{K_s}	J–H	σ_{J-H}	H–K_s	σ_{H-K_s}	J–K_s	σ_{J-K_s}
21	2 40 23.4	–34 43 22	13.401	0.051	1.022	0.066	0.448	0.064	1.470	0.066
22	2 40 31.2	–34 28 44	13.078	0.040	1.002	0.060	0.645	0.054	1.647	0.060
23	2 40 52.2	–34 37 23	13.665	0.052	1.013	0.078	0.676	0.075	1.689	0.078
24	2 40 53.3	–34 12 13	13.231	0.044	1.011	0.064	0.723	0.062	1.734	0.064
25	2 41 03.6	–34 48 05	12.682	0.036	1.048	0.050	0.715	0.050	1.763	0.050
26	2 41 08.3	–34 35 52	13.438	0.051	1.136	0.066	0.447	0.067	1.583	0.066
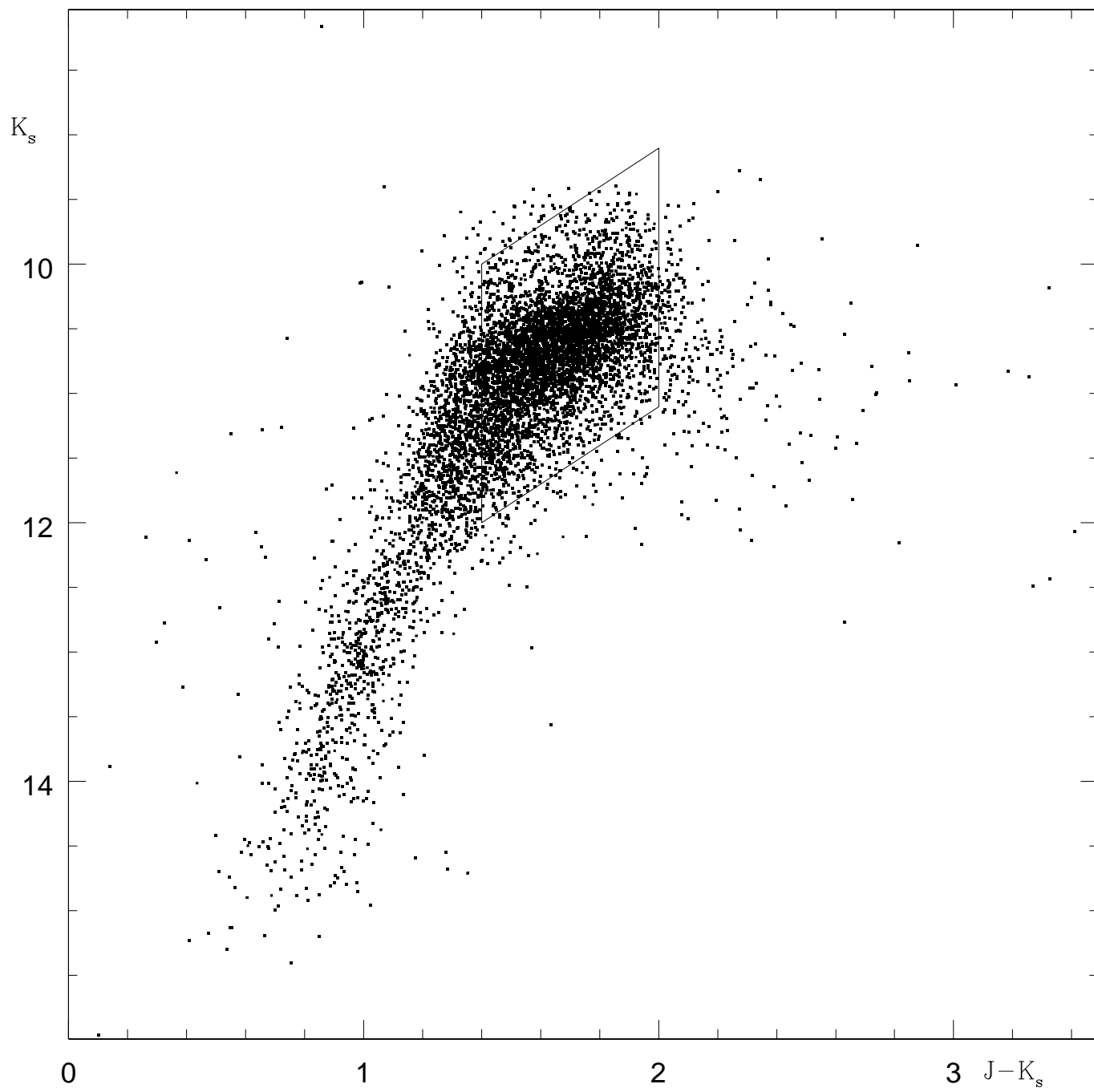
Table 2.   Cross identifications

id	alternate id's	V	B–V	comments	ref.
1	V8	19.1	2.1	new C star	1
2	V28	19.6	3.5	new C star	1
3	DK36 BM31	18.17	2.24	spectral type C	2,3
4	DK19 BM33	18.80	2.5	spectral type C	2,3
5	DK20 BM34	18.09	2.18	spectral type C	2,3
6	DK17 BM20	18.59	2.08	spectral type C	2,3
7	DK21 BM18 C1	19.34	2.38	spectral type C	2,3
8	DK46 BM1	17.49	2.79	spectral type C	2,3
9	C2	18.56		spectral type C	4
10	BM14 C5	18.98	2.66	spectral type C	3,4
11	BM5 C13	18.06	2.18	spectral type C	3,4
12	DK22 BM12	18.14	2.67	spectral type C	2,3
13	DK44 BM3	18.27	2.58	spectral type C	2,3
14	DK55	19.74	1.93	spectral type C	2,4
15	DK62	19.39	2.65	spectral type C	4
16	DK61 BM8	18.98	2.00	spectral type C	2,3
17	DK52	19.97	2.09	spectral type C	2,4
18	BM9 C7	28.75	2.58	spectral type C	3,4
19	V20 C10	18.43	2.66	spectral type C	1,4
20	DK65	18.97	2.57	spectral type C	2,4

Table 2—Continued

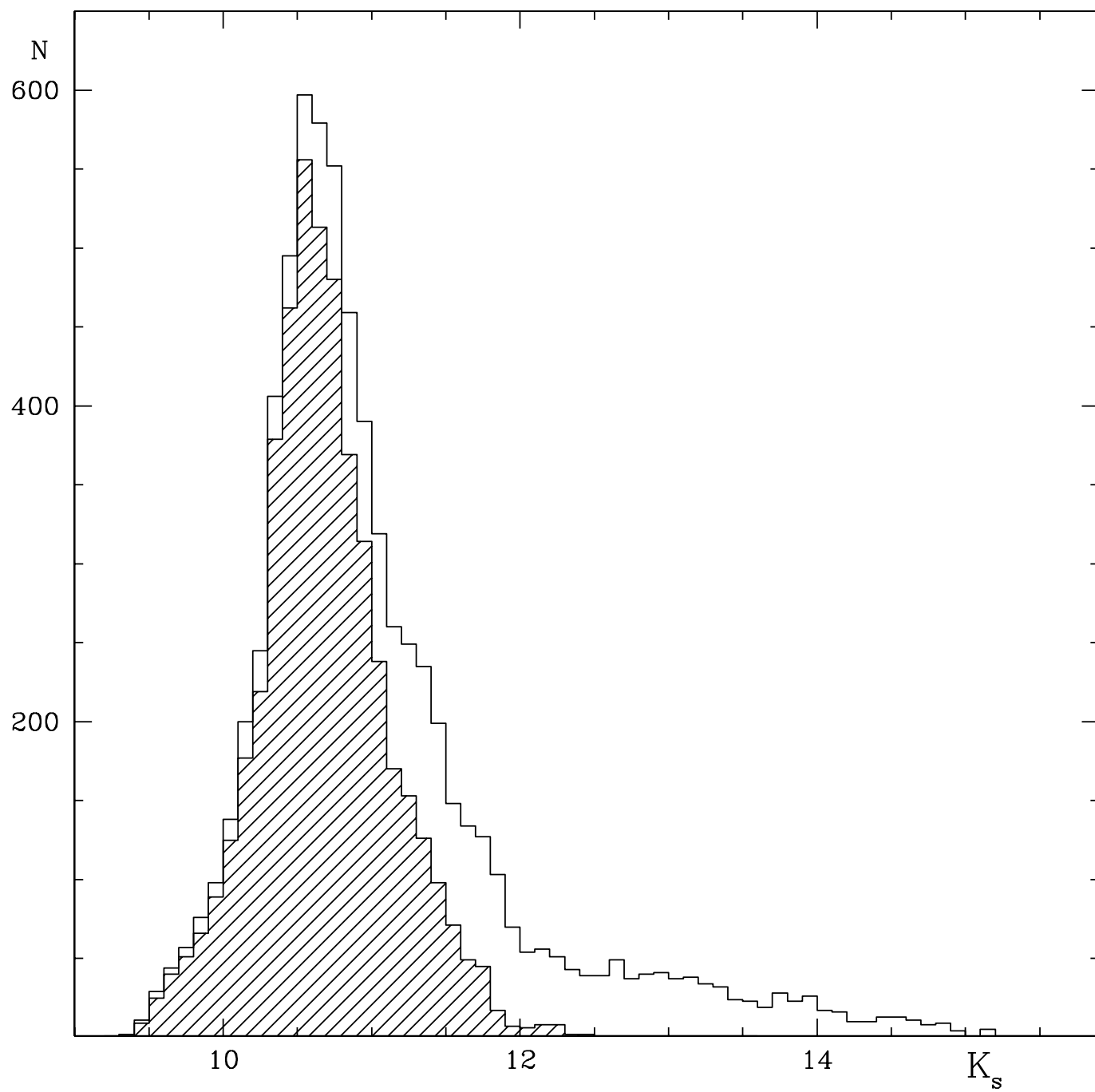| id	alternate id's	V	B–V	comments	ref.
21	C17	18.55	2.79	spectral type C	4
22				new C star	
23	DK23	18.81	1.76	new C star	2
24	V4	18.6	2.9	new C star	1
25				new C star	
26	R36	18.65	3.29	new C star	5

[1] Demers & Irwin (1987)

[2] Demers & Kunkel (1979)

[3] Frogel et al. (1982)

[4] Westerlund, Edvardsson & Lundgren (1987)

[5] Demers, Irwin & Kunkel (1994)

Morgan's data